SONY

ChromaTRU

ChromaTRU – Technical Review

Sony Professional LCD Monitors

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Introduction

During the past two decades, LCD devices have become an essential element in almost all electrical appliances – including handheld calculators, cellular phones, PDAs, video games and computer displays. While such applications have primarily used LCD technology for its portability and ease of handling, on-going research and studies have now elevated LCD picture performance to a level approaching conventional CRTs. The number of consumer LCD televisions seen on the market today and their continual picture enhancements are clear demonstrations of this progress.

Today's LCD display devices, used by many professional video equipment suppliers, have reached a level well suited for professional picture monitoring in both production and broadcast applications. While their brightness, contrast and viewing angle limitations were once a concern, these have now been brought to an acceptable level for most picture monitoring applications. However, one issue has yet to be resolved, an effect inherent in all LCD devices - lack of colour matching between multiple monitors, and gamma curve discrepancies between CRTs – features that cannot be overlooked in high-end picture monitoring applications.

The Sony LMD Series of LCD monitors* provide a revolutionary solution to these issues. Using innovative technology, they not only allow perfect colour matching between multiple LCD monitors but also achieve white balance and gamma colour characteristics comparable with a CRT display.
This manual introduces the innovative technology used to achieve these benefits, and includes a glossary on related terminology for a clear understanding.

Reading through this manual will allow you to reinforce your demonstrations when you have a unit on hand, or allow you to logically explain how this mechanism works to lead your customers to a demo request.
We hope this document serves as an invaluable tool in your LMD sales activities.

* Available on High-grade LMD monitors

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❶ The reference for today's video systems – CRT colour reproduction

From the advent of the first broadcast system, all video system components have been designed with consideration to the characteristics of a CRT system. This was the natural choice for many years given that CRT television was the only device for delivering video to household audiences.

A most well-known consideration is the 'reverse gamma' characteristics of a studio video camera. Although the raw light-to-signal characteristics exhibit a linear relation, all video cameras process their signals using a 0.45 gamma curve.

This gamma was required to compensate for the CRT's unique gamma curve of 2.2, making the entire 'image capture to light display' a linear system.

Today's technology offers a variety of display systems from LCD to plasma and EL displays – none of whose raw characteristics match the conventional CRT.

The issue of whether these technologies can be used in a professional environment is clear – how close can these match the characteristics of a CRT.

The LMD Series ChromaTRU technology has finally given a solid answer.

❷ The issues of using LCD technology in professional video systems

❷① The limitations of LCDs today

For many reasons, including its longevity, stability and high-paced improvements, LCD technology has become the choice for replacing the professional CRT by all prominent manufacturers. However, critical improvement issues still remain to make this transition.

The following list shows these issues at a glance. These are attributable and common to the raw characteristics of all LCD devices.

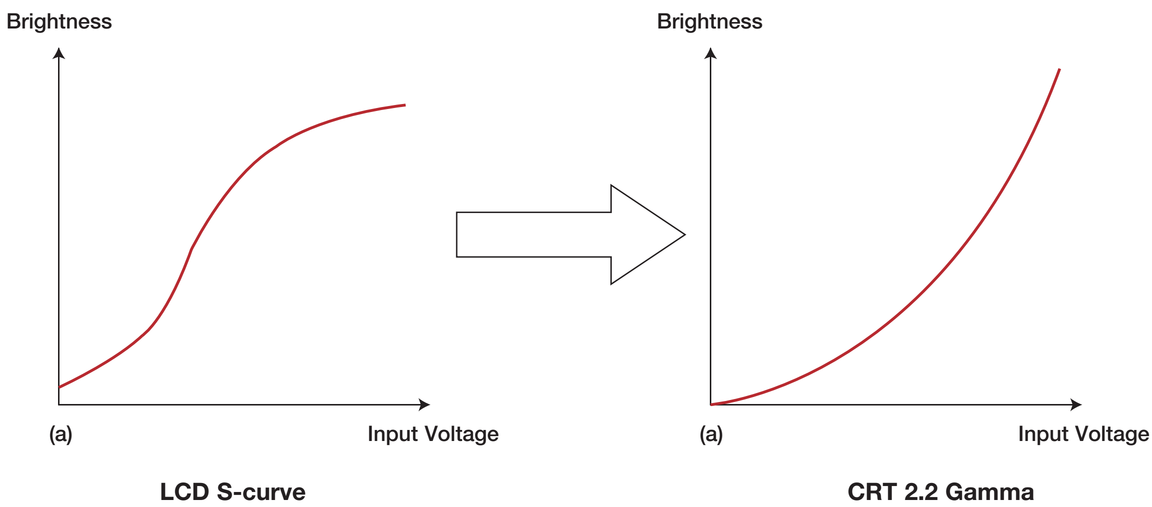
1. **Inconsistent colour temperature or colour 'temperature shifts' throughout the grayscale, from black to white.**
2. **Inconsistent colour reproduction from panel to panel even between same monitor models.**
3. **Gamma characteristics are compensated to try to match CRT but a CRT-like gamma is not achieved.**

❷② The LCD characteristics that cause such problems

The raw 'input voltage versus light output' characteristics of an LCD monitor illustrates an alphabet 'S-shaped' curve, which is very different from a CRT's gamma. What adds more difficulty is that this 'S-shaped' curve varies on a panel-to-panel basis. The key to achieving a CRT-like gamma depends on how accurately this 'S-shaped' curve can be electrically compensated to match a 2.2 gamma. However, while the amount of compensation is significant, the fact that compensation must be achieved between two non-linear curves introduces extra difficulty.

A second issue is that CRTs use colour phosphors and LCDs use colour RGB filters to reproduce colours. Although highly pure RGB filters are used in professional LCD monitors, this different mechanism is another reason why the colour of an LCD display does not perfectly match a CRT, either on a video monitor or on the CIE colour map.

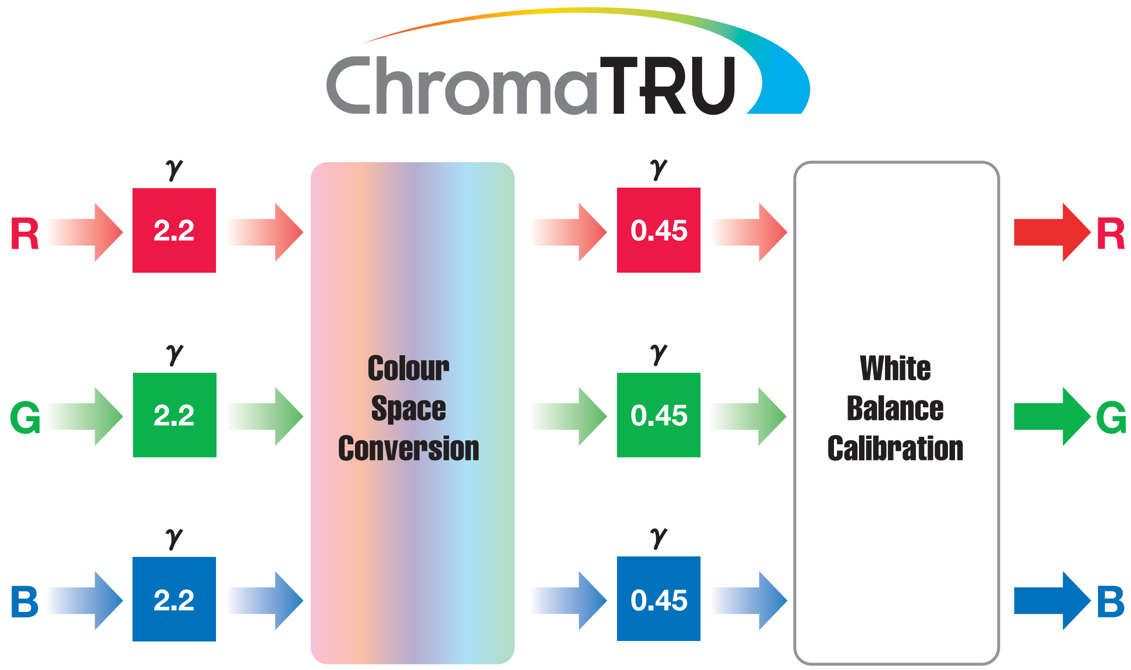
Figure ❶



❸ The Sony solution to these issues – ChromaTRU colour processing

Intensive research by Sony has led to the development of a method to overcome such problems – ChromaTRU processing – an innovative colour calibration technology that eliminates these colour discrepancies. The diagram below shows a simplified flow of this ChromaTRU technology.

Figure ❷



❸① Colour Space Conversion

ChromaTRU technology comprises two main processes. The first process is called 'Colour Space Conversion'.

The colour coordinates of an LCD's RGB colour filters and those of a CRT's RGB phosphors do not coincide on the CIE colour map. This fact holds true for all LCD displays. As these 'RGB colour primaries' are the basis of reproducing colour in additive mixing, this means that the same colour cannot be obtained from the two devices for the same RGB input signal (refer to Figure-3). This colour discrepancy also varies from panel to panel since the colour filters and backlight of each LCD panel present different characteristics even within the same series of models.

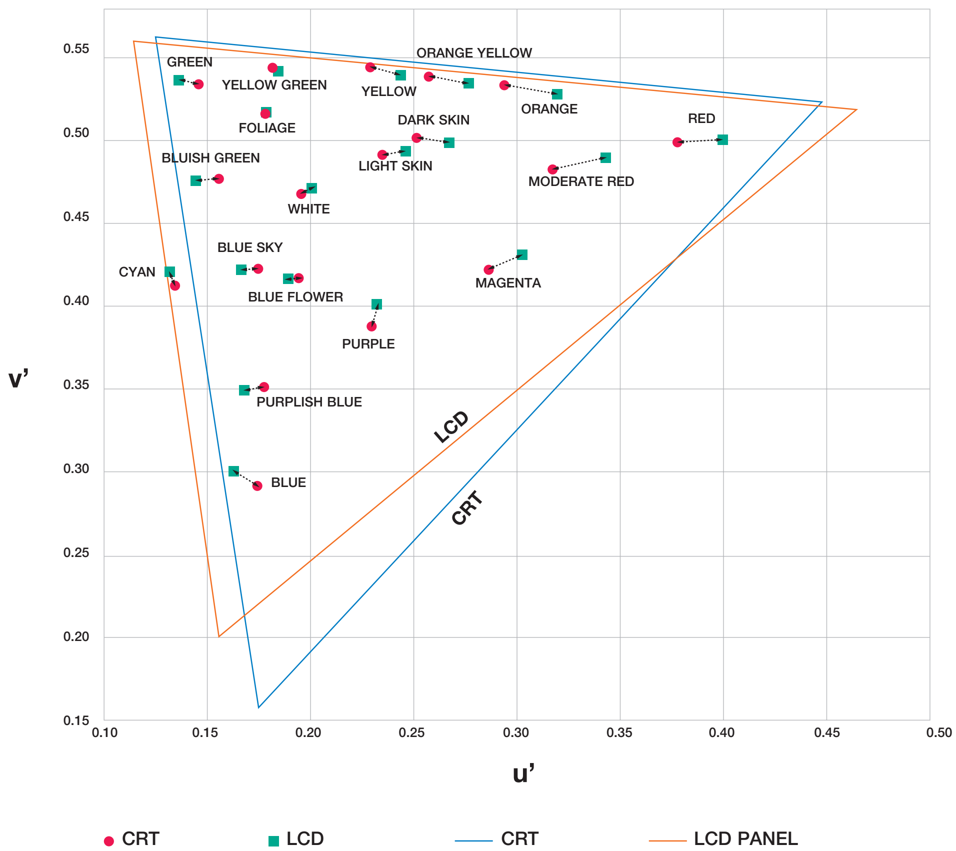
To compensate for this 'colour mismatch' between LCD colour filters and CRT phosphors, Colour Space Conversion electrically creates new colour primaries, from its native filter primaries, that emulate RGB phosphors. This is achieved by using a colour conversion matrix that is customised for each LCD panel. Although the colour space becomes slightly smaller than a CRT, these new primaries make the light emitted from the LCD panel the same as a CRT. RGB primaries are handled as linear signals, thus Colour Space Conversion must also be performed in the linear domain.

Since video signals are subject to a 0.45 gamma in the video camera, the RGB signals fed to Colour Space Conversion must be reversed into their linear forms by applying a 1/0.45 gamma ($\fallingdotseq$ 2.2). In ChromaTRU, this conversion is processed with high precision to avoid any degradation. Once the Colour Space Conversion matrix calculates the new colour primaries, the RGB signals are converted back into their non-linear forms, again with high precision.

Figure 3

CIE COLOUR COORDINATES

The CIE u'v' chart is used to evaluate the light output of display devices. In this diagram, the raw light output of an LCD is compared with that of a CRT. The triangular areas show their different colour reproduction capabilities (Colour Space). The green and red dots indicate the colour of light output from an LCD and that from a CRT for certain RGB input signals. Note that the same light colour is not obtained for the same video input.



❸ The Sony solution to these issues – ChromaTRU colour processing

❸② White Balance Calibration

Following the Colour Space Conversion, a second important process called 'White Balance Calibration' is applied. This process has two significant roles; it compensates for the gamma discrepancies between the LCD panel and standard CRTs, and further eliminates any white balance inaccuracies typically seen in LCD monitors. With conventional LCD monitors, white balance adjustment has been a challenging task. This is because the native characteristics of an LCD, combined with its colour filters is such that colour temperature slightly shifts depending on the input signal's luminance level – regardless of the monitor being set to a specific colour temperature.

In general, adjusting white balance makes all other colours come into correct colour balance. This means that the gamma curves of the RGB channels must be the same since a consistent ratio must be maintained between them.

In other words, the light output between the RGB LCD sub-pixels must have the same ratio for all different video levels. In ChromaTRU White Balance Calibration, a significant 208 compensation points are measured and used, from black level to white, to clamp and maintain a consistent colour temperature. At the same time, each RGB channel is precisely adjusted to follow an accurate 2.2 CRT-like gamma. Combining this New White Balance Calibration function with the earlier mentioned Colour Space Conversion allows colour matching between multiple LCD monitors with gamma characteristics just like CRTs.

❸③ The actual results

The effect of ChromaTRU processing can be seen on the CIE u'v' chart. With CSC*1 and WB*1 Calibration activated, LMD Series LCD monitors*2 reproduce colours almost identical to CRTs. In the chart opposite, most yellow dots (CRT) and blue dots (CSC + WBC) are located in the same position, meaning the same light output is obtained for the same video input.

*1 Hereafter, Colour Space Conversion and White Balance Calibration are abbreviated as CSC and WBC, respectively

*2 Available on High-grade LMD monitors only

Figure 4

CIE CHART WITH COLOUR SAMPLES

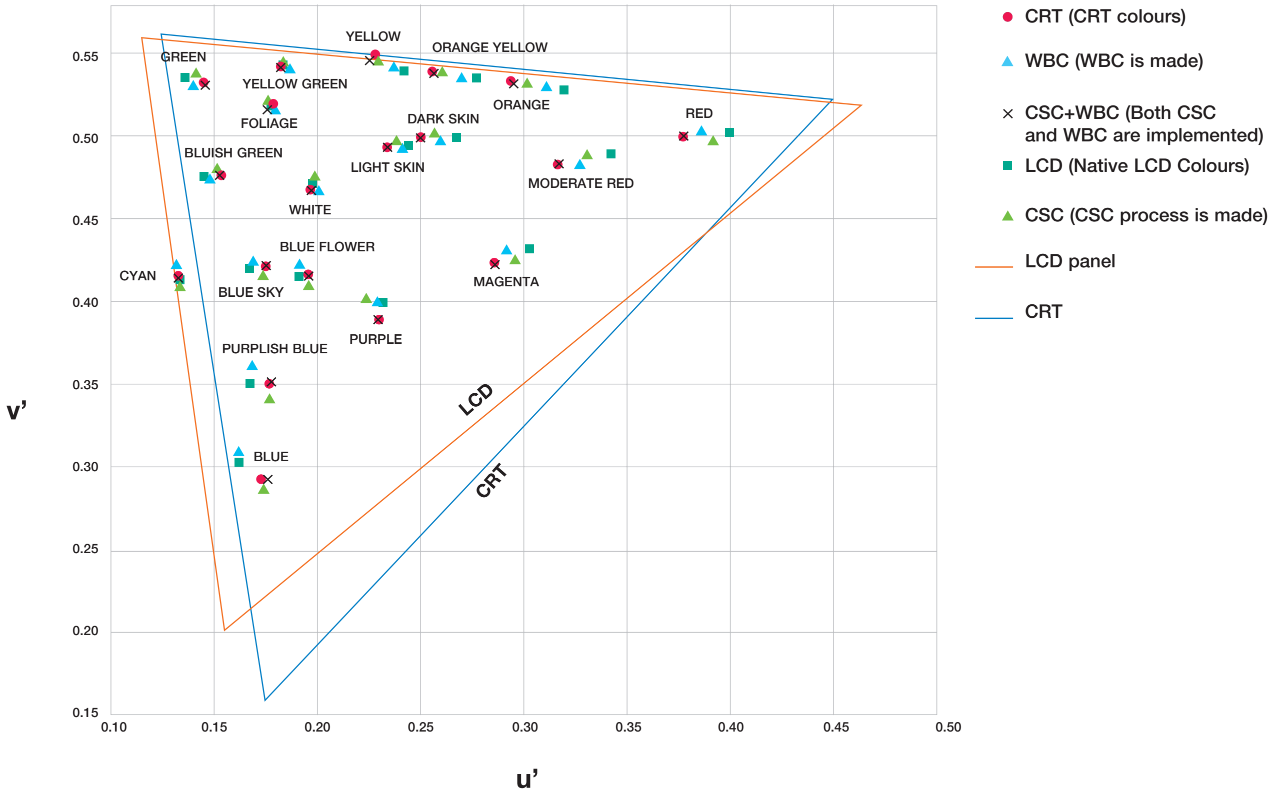


Figure 5

A colour comparison between CRT and LCD, with different combinations of CSC and WBC applied. The colour tiles indicate that the LCD colours obtained using WBC+CSC (right bottom corner) look almost identical to the colours reproduced from a 'CRT' (centre tile).

LEGEND

LCD Native LCD Colour
CRT CRT Colour
WBC White Balance Calibration applied
CSC CSC process applied
WBC+CSC: CSC and WBC applied

COLOUR TILE

Light Skin Bluish Green Purplish Blue

3 The Sony solution to these issues – ChromaTRU colour processing

3④ The actual adjustment process

As has been discussed, the native colour characteristics of an LCD panel are far different from a CRT. They are also different from LCD to LCD. The goal with ChromaTRU process (Colour Space Conversion and White Balance Calibration) is to generate an LCD drive voltage that displays the input RGB signal as it would be seen on a CRT. In the below figure, this LCD drive voltage is indicated as R", G", B". The output of CSC is indicated as R', G', B'. A key point to note is that CSC is a matrix process and the same conversion calculation is applied to all different levels of RGB input. In contrast, White Balance Calibration is a conversion process that differs for each RGB signal value and thus a lookup table (a numerical mapping table) is used. This table maps the colour space corrected R'G'B' signal values to the White Balance corrected R"G"B" signal values – the signals that actually drive the LCD display. In actuality, the lookup table has as many as 208 variations of mapping.

As earlier mentioned, the matrix coefficients of CSC and lookup table values of White Balance Calibration are precisely calculated on an LCD panel basis at production. This calculation is done by measuring the raw light output of the LCD panel*1 and comparing it with the output that would be obtained if the same RGB input was displayed on a CRT. A sophisticated analysis examines the results of this comparison*2 and sets the correct matrix coefficients and lookup table values. Once these are calculated, the data is registered to the LCD panel memory from the analysing system so the Colour Space Conversion matrix and White Balance lookup table are optimised for that panel.

*1 The light output without Colour Space Conversion and White Balance Calibration.

*2 In actuality, the light output of each RGB channel is compared both in its CIE x/y-coordinates and CIE u'/v-coordinates.

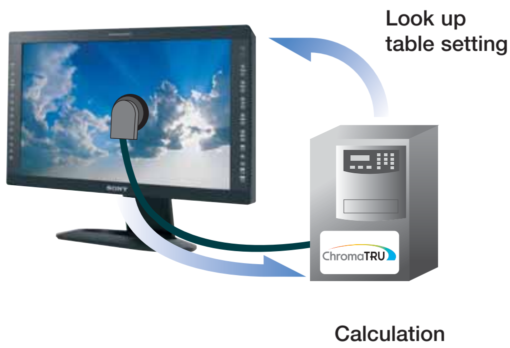


Figure 6

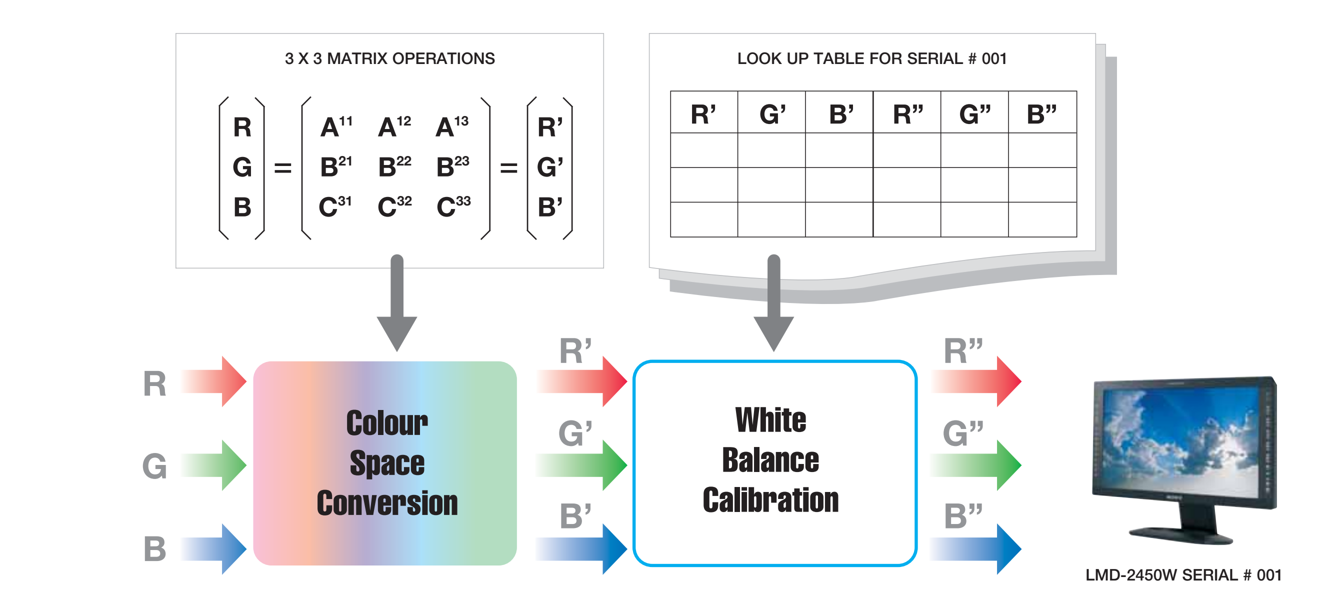


Figure 7

4 Conclusion

The different colour characteristics of LCDs and their inconsistency from panel to panel had made it a challenge to position them as a replacement for CRTs. Sony ChromaTRU technology now overcomes this challenge, bringing CRT colour reproduction and precise panel-to-panel colour matching into the world of professional LCD monitoring.

Glossary

ADDITIVE MIXING

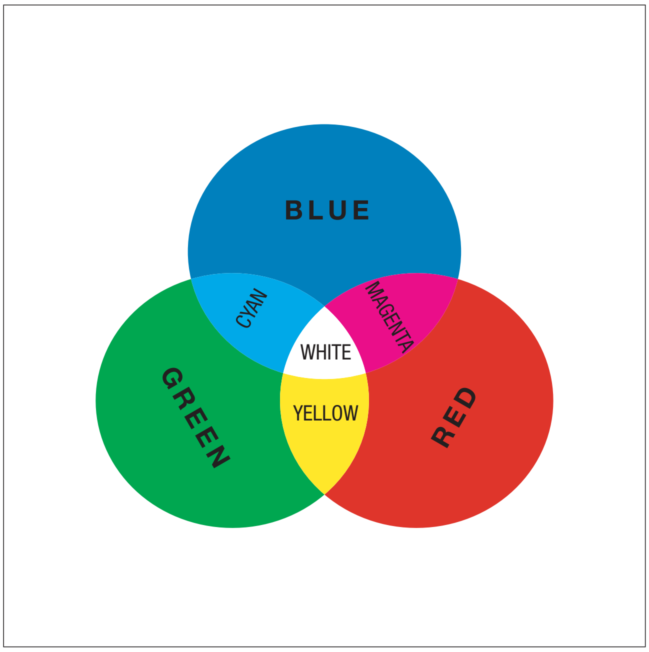
Prior to the development of the color video system, experiments in colorimetry proved that most colors visible to the human eye could be composed using the three primary colors, Red (R), Green (G), and Blue (B). This also means that almost any visible color can be separated into a certain combination/amount of the three primary color components. This principle is called "Additive Mixing." (Fig. A)

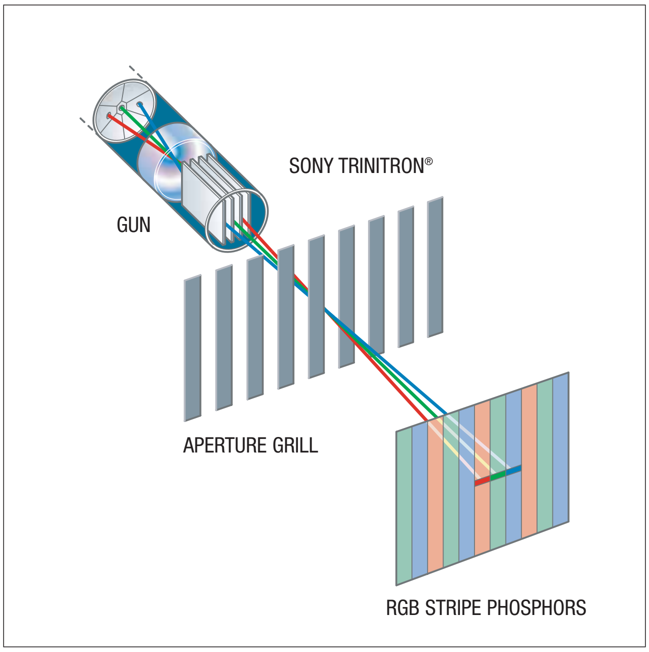
The mechanism of reproducing color images on a video monitor is based on this principle and represents a good example for understanding how additive mixing works.

Within the video monitor CRT tube, there are three R, G, and B guns. Each gun is used with its associated phosphor, which lights in Red, Green, or Blue when stimulated by the gun's electron beam. (Fig. B) When the CRT tube receives a color video signal, the R, G, and B guns emit electrons (electron beams) towards their phosphors in proportion to the amount of R, G, and B components contained in the signal.

This results in the emission of Red, Green, and Blue light, with intensities proportional to their associated electron beams. To the human eye, these lights are perceived as a single ray of light, with the appropriate color reproduced when viewed from a certain distance.

The mechanism of a color video camera uses a reverse function of a video monitor. Light entering the camera lens is first separated into the three primary colors using a prism system or color filters These R, G, and B color lights are then converted into R, G, and B signal voltages at their associated R, G, and B imager sensors (CCD or CMOS).After amplification, the R, G, and B signals are processed into the desired signal format (component, composite, etc) to construct the video output signal.





GAMMA

Gamma (γ) is a numerical value that indicates the response characteristics between the brightness of a display device (such as a CRT or flat panel display) and its input voltage. CRT tubes, due to their beam mechanisms, exhibit a characteristic in which the brightness of the CRT and the input voltage retain an exponential relation, instead of a proportional one (Fig. 8(A)). The exponent index that describes this relation is the CRT's gamma, which is usually around 2.2.

Mathematically, this gamma is expressed by the equation:

$$L = V$$

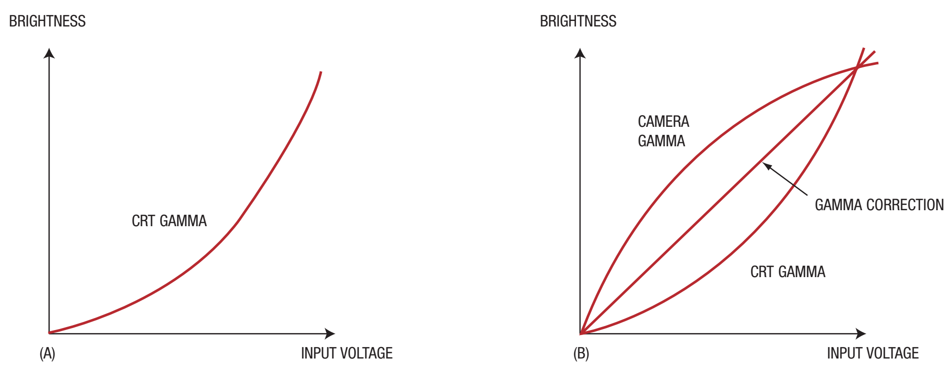
where L is the CRT brightness and V is the input voltage.

On a CRT screen, this means that dark areas of a signal will look much darker than they actually are, and bright areas will look much brighter than they should be.

Needless to say, video systems must have a linear relation from the light-capturing device to the light-output device. Thus, the CRT's exponential characteristics must be compensated for somewhere in the system chain. This compensation is called gamma correction, and is performed within the image-capturing device - the video camera.

The goal in compensating for a CRT's gamma is to create a camera output signal that has a reverse relation to the CRT's gamma. In this way, the light that enters the camera will be in proportion to the brightness of the CRT picture tube (Fig. 8(B)). Technically, the camera should apply a gamma correction of about of 1/γ. This exponent γ'(1/γ) is what we call the camera's gamma, which is about 1/2.2 or 0.45.

Figure 8



Glossary

COLOUR TEMPERATURE

Colour temperature is a parameter used to describe the spectrum distribution of the light that an illuminant emits. For video or PC monitors, it is used to describe their base operating colour, which is measured using the colour white. Illuminants or monitors with low colour temperatures tend to look reddish, while those with high colour temperatures tend to look bluish.

In order to understand why we describe a monitor's colour using 'temperature', a brief review of colourimetry is required.

Researchers in colourimetry discovered that the spectral distribution of light emitted from a piece of carbon (a black body that absorbs all radiation without transmission and reflection) is determined only by its temperature. When heated above a certain temperature, carbon will start glowing and emit a colour spectrum particular to that temperature. This discovery led researchers to use the temperature of heated carbon as a reference to describe different spectrums of light. This is called colour temperature.

Coming back to our subject, it might sound strange that a 'temperature' is used to describe a monitor's base operating colour, white. However, as mentioned above, colour temperature can describe the spectral distribution of different colour tones using a single temperature number, also making it handy to describe the spectral distribution of a monitor's white colour – the colour that determines the monitor's overall picture colour. For example, if a monitor is set up to display images with a reddish colour tone, this adjustment can be precisely expressed using the monitor's colour temperature.

Light Source	Colour Temperature (approx.)
Skylight	12000 K – 18000 K
NoonSunlight	4900 K – 5800 K
Sunrise and Sunset	3000 K
12 V/100 W Halogen Lamp	3200 K
Candlelight	2900 K

WHITE BALANCE

To achieve consistent colour reproduction on a monitor, the monitor must maintain the same colour temperature throughout the entire gray scale. In other words, the monitor must provide the same colour tone for all luminance levels of white – from black to gray, onto 100% white. This is called white balance.

Monitor white balance is adjusted during production for typical colour temperatures and adjustment by the operator is usually not required. For example, if the operator selects 6500K for the monitor's colour temperature, the monitor will maintain the same white balance – that is, the white balance that translates into 6500K colour temperature – throughout the entire gray scale.

Professional monitors do however, allow white balance and colour temperature to be adjusted should the desired colour temperature setting not be preset in the monitor.

In the case of LCD monitors, white balance tended to shift according to signal luminance level, making colour matching between monitors a challenge. This issue has now been resolved using Sony ChromaTru technology.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